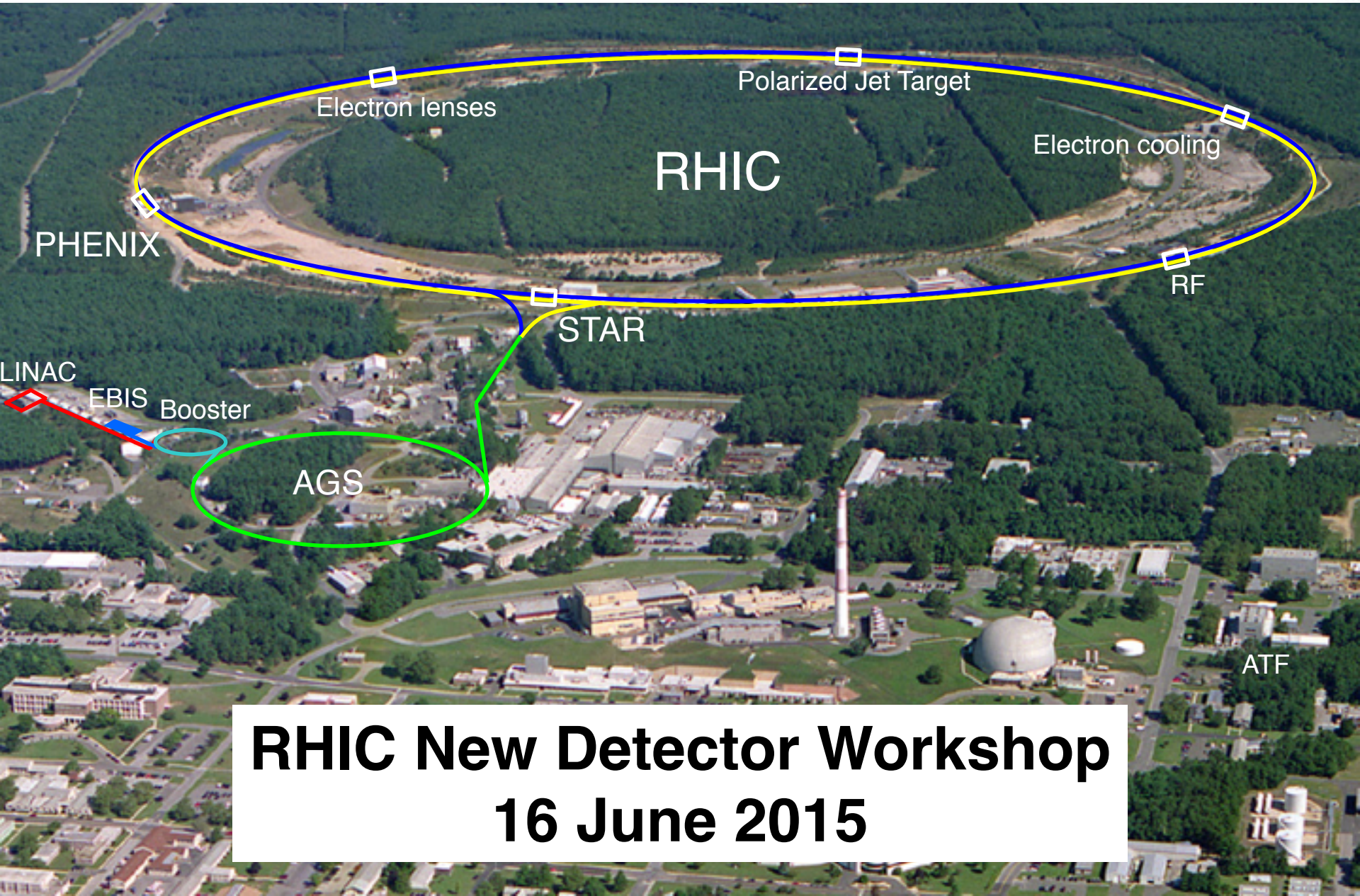
Completing the Scientific Mission of RHIC



RHIC New Detector Workshop
16 June 2015

The overarching scientific question:

How do asymptotically free quarks and gluons create the near-perfect liquidity of the QGP?

or

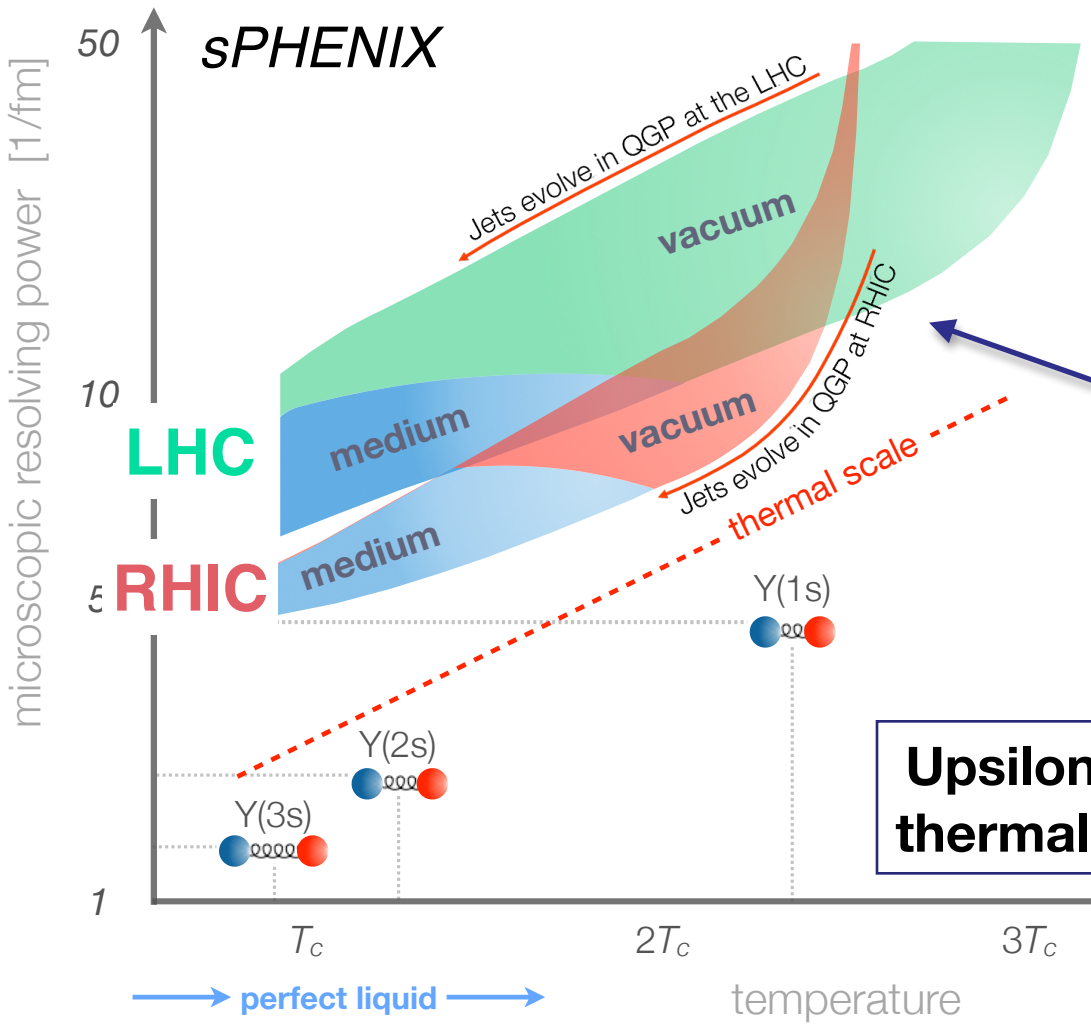
What degrees of freedom not manifest in the QCD Lagrangian produce the near-perfect liquidity of the QGP?

The (experimental) answer:

Deploy probes with a resolution that reaches well below the thermal ~ 1 fm scale of the bulk:

Jets & Upsilon states

Probing scales in the medium

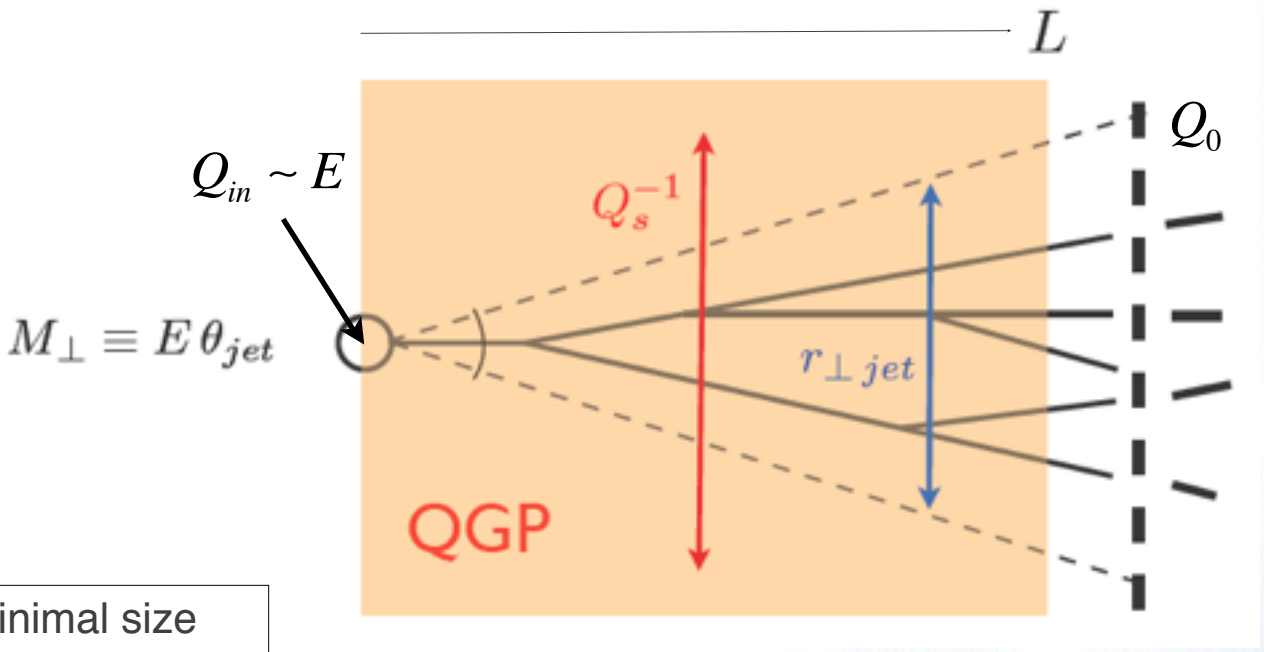


How does the perfect fluidity of the QGP emerge from the asymptotically free theory of QCD?

Jets probe sub-thermal length scales

Upsilon states probe thermal length scales

Why jets are a good medium probe



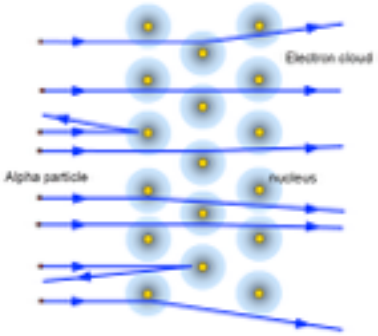
Q_s^{-1} = minimal size of probe to which the medium look opaque

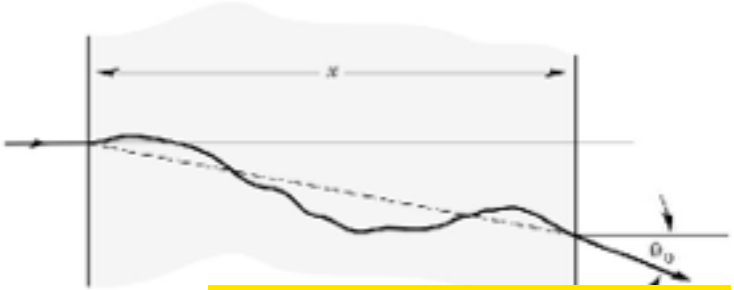
Momentum scale of medium $Q_s = \sqrt{qL} \approx m_D \sqrt{N_{\text{scatt}}}$

Transverse size of jet $r_{\perp\,\text{jet}} = \theta_{\text{jet}} L$

“Rutherford” meets QGP

At what scale do discrete scattering centers “dissolve” into a collectively acting, ccontinuous medium?



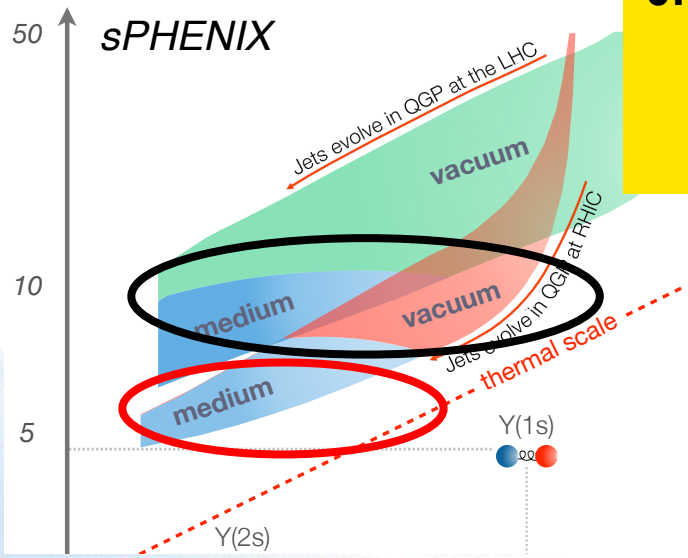


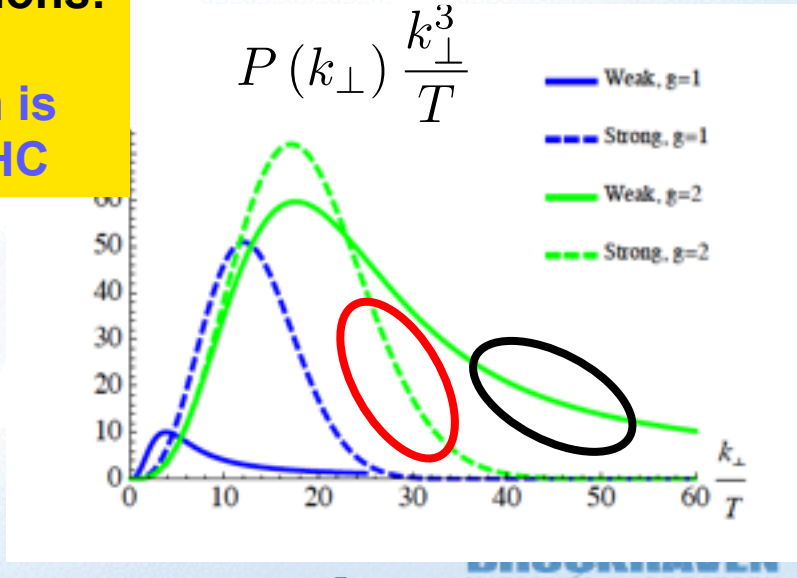
Point-like scattering centers: $1/k_T^4$ tail

Quasi-continuous medium: Gaussian

sPHENIX will sample 0.6 trillion collisions!

10x more than is possible at LHC

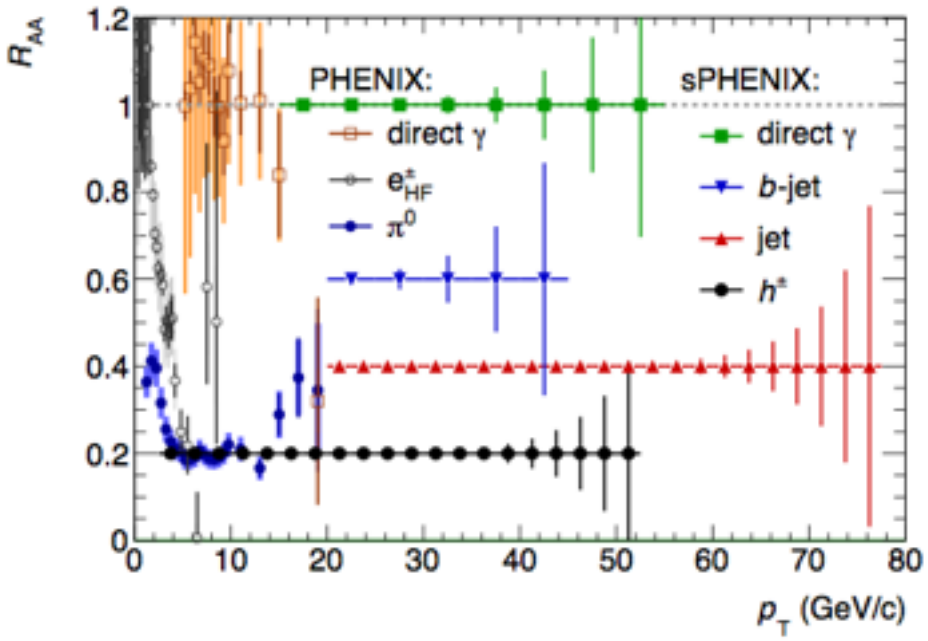


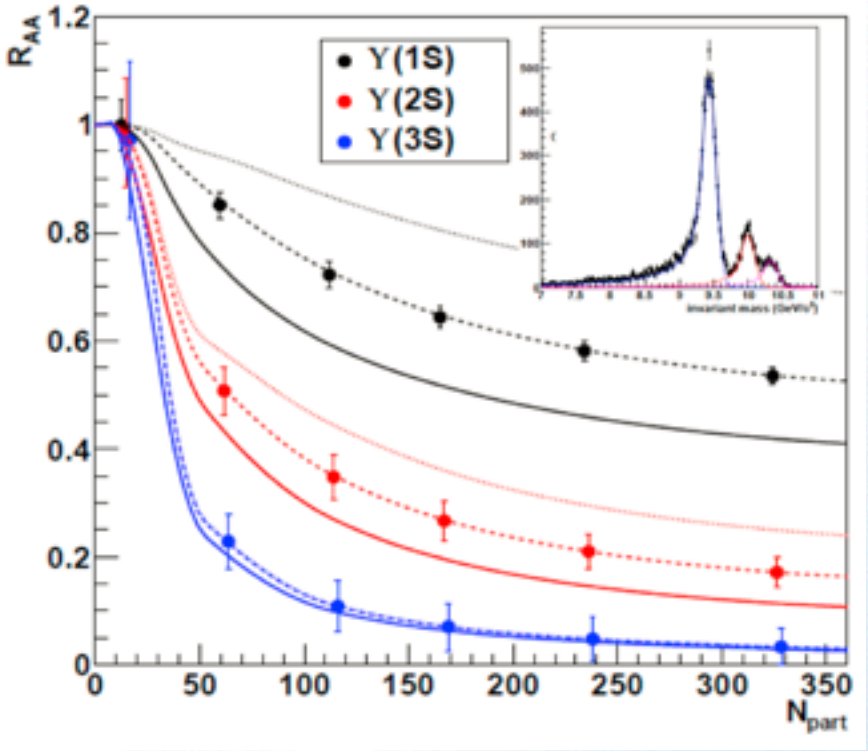


Jets & Upsilon states

sPHENIX capabilities

Complete calorimetric jet spectroscopy





Completely resolved Upsilon spectroscopy

The Strategy

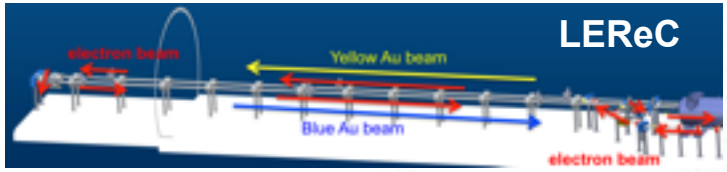
Completing the RHIC mission in 3 campaigns

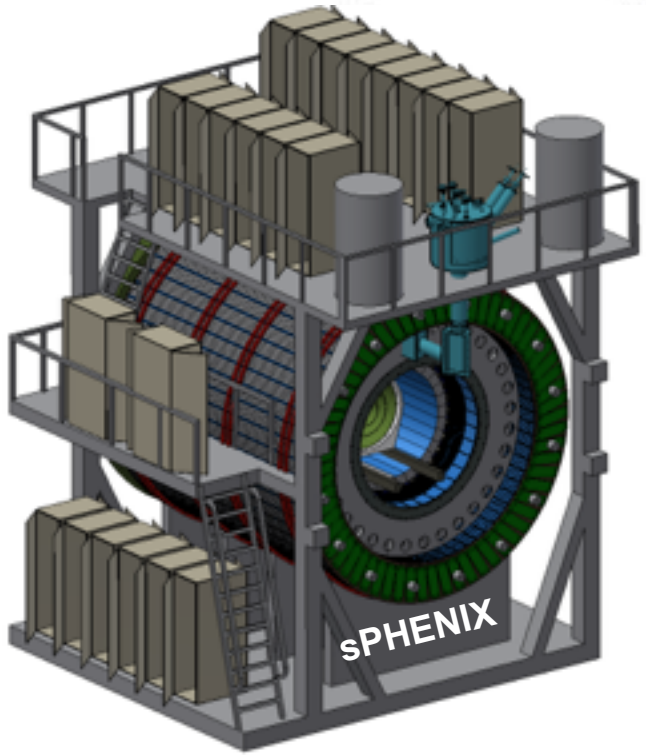
Status: RHIC-II configuration is complete

- Vertex detectors in STAR (HFT) and PHENIX
- Luminosity reaches 25x design luminosity

Plan: **Complete the RHIC mission** in 3 campaigns:

- **2014–17: Heavy flavor probes of the QGP using the micro-vertex detectors; Transverse spin physics**
- *2018: Install low energy e-cooling*
- **2019/20: High precision scan of the QCD phase diagram & search for critical point**
- *Install sPHENIX*
- **Probe QGP with precision measurements of jet quenching and Upsilon suppression**
- **Spin physics and initial conditions at forward rapidities with p+p and p+A collisions ?**
- *Transition to eRHIC*





RHIC remains a unique discovery facility

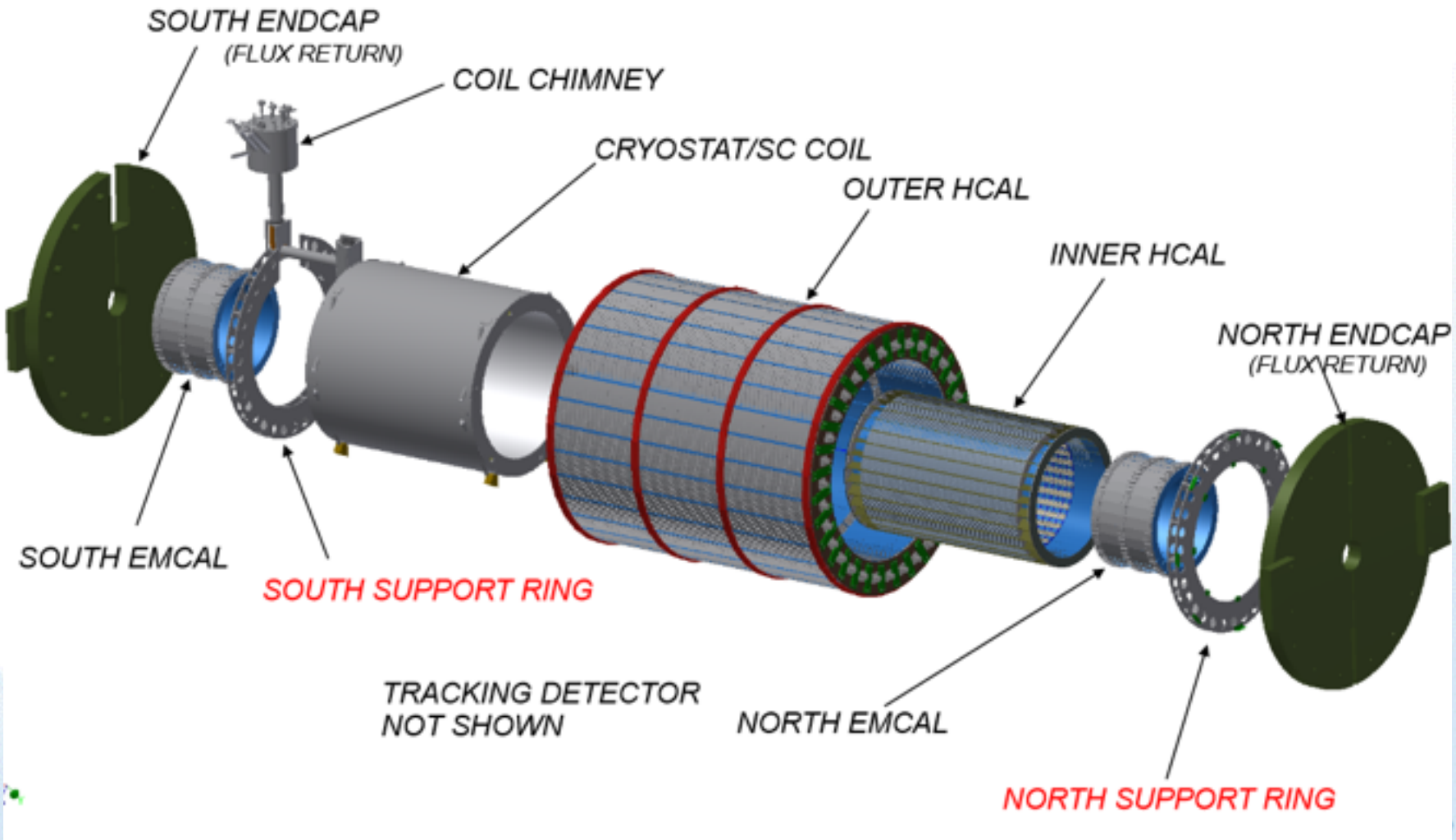
Completing the RHIC science mission

- **A unique forefront science program with tremendous discovery potential that is ONLY possible with RHIC:**
- **Quantify the transport properties of the QGP *near* T_c using heavy quarks as probes** (together with LHC)
- **Measure gluon and sea quark contributions to proton spin and explore coupled momentum-spin dynamics of QCD**
- **High statistics map of the QCD phase diagram, including possible discovery of a critical point**
- **Probe internal structure of the *most liquid* QGP using fully reconstructed jets and resolved Upsilon states as probes** (together with LHC)
- **Refine the physics program of an EIC with studies of *polarized* pp and pA collisions in forward kinematics**
- **RHIC enabled R&D to retire major risks of eRHIC design**

Proposed run schedule for RHIC

Years	Beam Species and	Science Goals	New Systems
2014	Au+Au at 15 GeV Au+Au at 200 GeV ^{3}He+Au at 200 GeV	Heavy flavor flow, energy loss, thermalization, etc. Quarkonium studies QCD critical point search	Electron lenses 56 MHz SRF STAR HFT STAR MTD
2015-16	p↑+p↑ at 200 GeV p↑+Au, p↑+Al at 200 GeV High statistics Au+Au Au+Au at 62 GeV ?	Extract η/s(T) + constrain initial quantum fluctuations Complete heavy flavor studies Sphaleron tests Parton saturation tests	PHENIX MPC-EX STAR FMS preshower Roman Pots Coherent e-cooling test
2017	p↑+p↑ at 510 GeV	Transverse spin physics Sign change in Sivers function	
2018	No Run		Low energy e-cooling install. STAR iTPC upgrade
2019-20	Au+Au at 5-20 GeV (BES-2)	Search for QCD critical point and onset of deconfinement	Low energy e-cooling
2021-22	Au+Au at 200 GeV p↑+p↑, p↑+Au at 200 GeV	Jet, di-jet, γ-jet probes of parton transport and energy loss mechanism Color screening for different quarkonia Forward spin & initial state physics	sPHENIX Forward upgrades ?
≥ 2023 ?	No Runs		Transition to eRHIC

sPHENIX exploded view



BaBar magnet @ BNL

sPHENIX Cost/Schedule

- Science review July 2014
- Science review follow-up 30 April 2015
- Cost and schedule review in Spring 2016
- PHENIX ends data taking after Run 16
- BaBar magnet high-field test in mid 2016
- sPHENIX construction start in mid 2017
- sPHENIX installation: 2018 − 2020
- First RHIC run with sPHENIX in FY2021

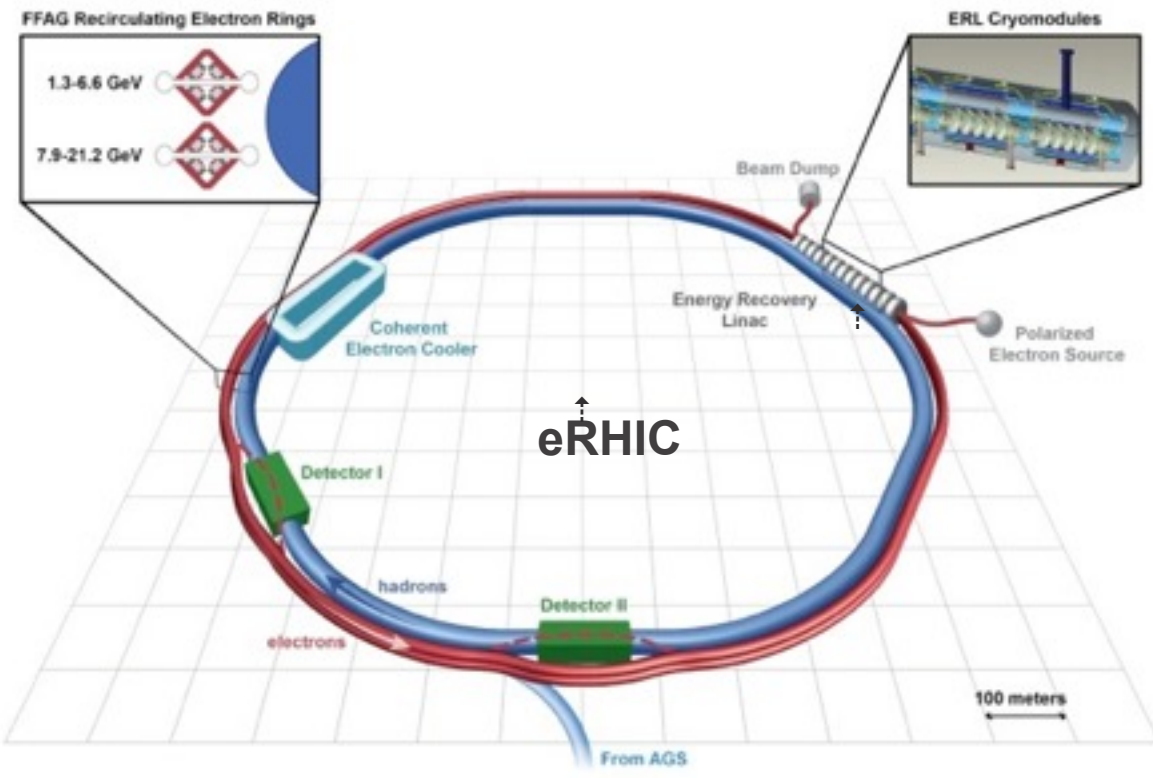
- TPC: $55-60M (FY15$)
- Sources: Redirected RHIC operations funds
  - Expt. ops (PHENIX 2017-20), RHIC incremental run costs (2018)

Beyond RHIC

eRHIC Design

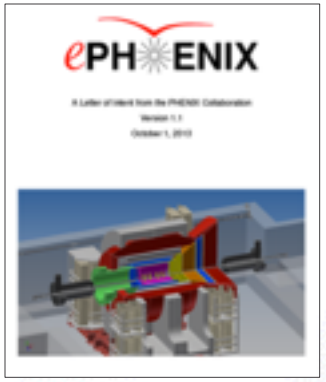
eRHIC ERL + ring design @ $10^{34}/cm^2s$

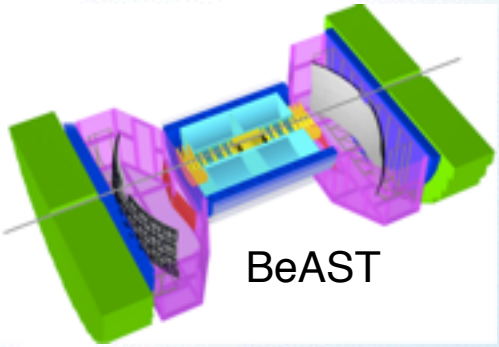
Up to 21.2 GeV e^- + 255 GeV p or 100 GeV/u Au



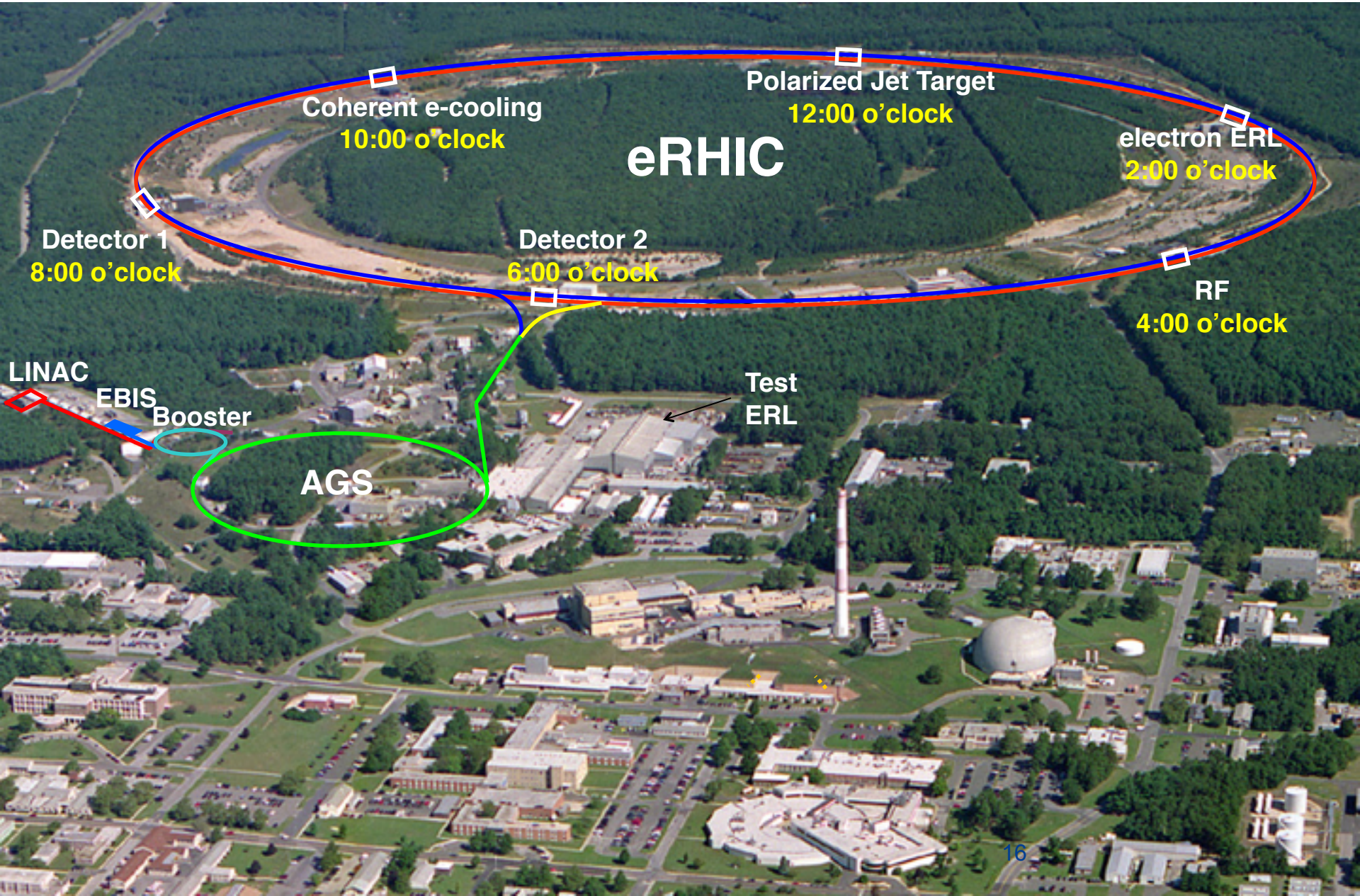
When completed, eRHIC will be the most advanced and energy efficient accelerator in the world

Detector Options

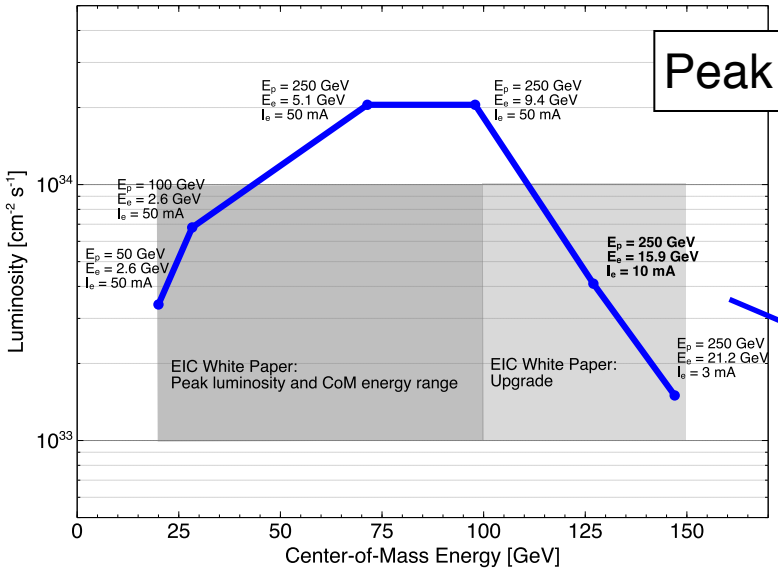




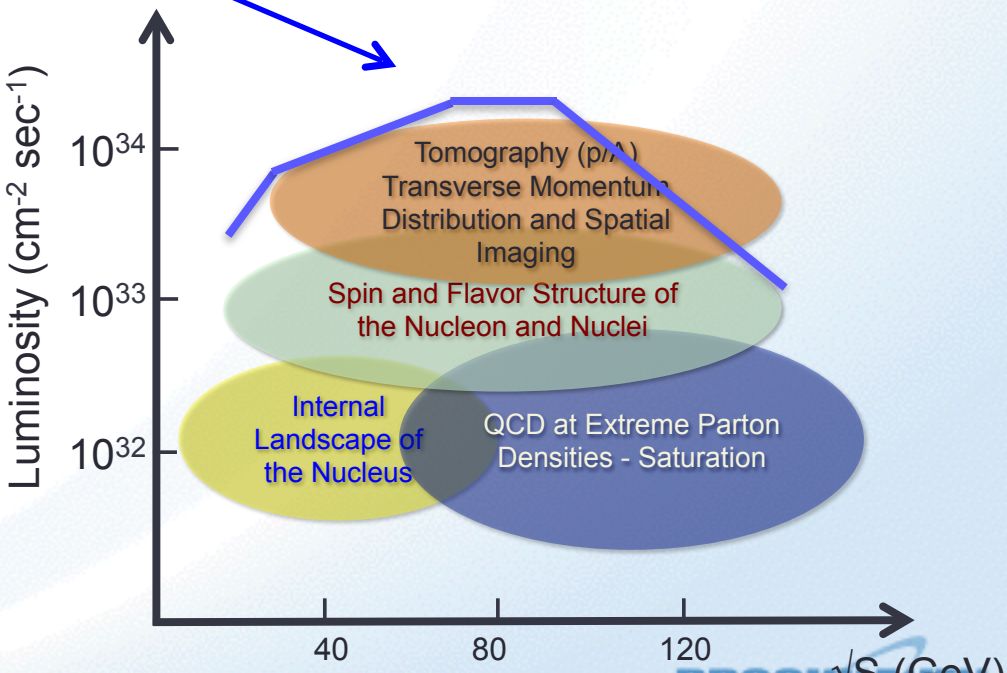
eRHIC – Polarized Electron-Ion Collider



Design goals match physics goals



EIC requirements for physics opportunities



Detector requirements:

- **Good PID (*e*/*h* and π, *K*, *p*)**
- **Wide acceptance to reach edges of kinematic range**
- **Ongoing generic EIC detector R&D program**

RHIC Collaborations

PHENIX

PHENIX plans to end data taking after Run 16.

Anticipate decommissioning starting in mid-2016.

Data analysis to continue for several more years.

STAR

With recent upgrades,STAR has become an extraordinarily versatile and powerful detector. It is critical for the success of Run 17 and the second Beam Energy Scan in 2019/20.

Important near-term future upgrades:

- iTPC (with China, will be considered by PAC next week)
- STAR CBM TOF (under serious discussion)

What will happen after BES II ?

- Concurrent data taking with sPHENIX without major upgrades?
- STAR runs with major upgrades for forward pp/pA/AA physics?
- IP6 becomes possible site of Day-2 EIC detector?
- Charge to STAR for draft proposal by mid-September and preliminary decision about possible path forward by mid-Fall 2015

“sPHENIX” Detector Workshop

A Large-Acceptance Jet and Upsilon Detector for RHIC

- Information for those interested in joining a new collaboration for a detector around the BaBar magnet
- Discussion of collaboration forming process:
  - provisional IB formation
  - working groups
  - preparation of constitutive meeting in early Fall 2015
- Connection to community interested in Day-1 detector for EIC

Structured after HEP project - collaboration model: Collaboration owns the science; project team owns the CD process. Both need to work well together for success. New collaboration is open to all; no inherited rights from prior involvement in sPHENIX proposal.

Workshop Goals

- Inform wider community about status of sPHENIX science and design / construction project
- Formation of working groups open to all interested scientists to develop and finalize design of major detector components:
  - EM and hadronic calorimeters
  - Tracking system
  - Electronics, DAQ, etc.
  - Requirements for conversion to an EIC detector
- Outline process toward formation of a new collaboration
- Formation of a provisional Institutional Board
- Schedule for constitutional collaboration meeting